A New Crowbar Logic Unit

E. J. Finnegan
R. F. Systems Development Section

A new crowbar logic unit has been designed and installed for the DSS 14 400-kW transmitter utilizing integrated circuits and plug-in modular construction. The logic unit of the crowbar consists of four detecting channels that generate and shape a new pulse which is used to trigger the crowbar. The crowbar is a device that short-circuits the power supply when a high voltage arc threatens to destroy the output klystron.

I. Introduction

A new crowbar logic unit was designed in the DSN high-powered transmitter. The unit has been operational at DSS 14 for almost one year and is also operational on the Venus radar and operational clock sync (OCS) X-band transmitters. A crowbar logic unit is a device used to detect data from different sensors and generate a pulse that is used to trigger the ignitron crowbar that protects the klystron (refer to Ref. 1). Klystrons operate at very high voltages (70 kV); therefore, they are subject to high-voltage arcs that may destroy the tube by disintegrating the cathode or cavities due to the stored energy in the filter discharged through the klystron. A mercury pool ignitron is used as a crowbar to protect the klystron when these arcs occur. The ignitron is placed directly across the high-voltage power supply and diverts the dangerously high currents through it, short-circuiting the filter while waiting for the main power supply to be disconnected from the line. This action takes place in less than ten microseconds, thus giving more than adequate protection to the klystron. The logic unit has utilized integrated circuits, principally the SE 518, which has a high switching speed of 55 nanoseconds and may be used as a Schmitt trigger, multivibrator, comparator, and amplifier, thus enhancing interchangeability. The only other transistor used is a 2N1711 for the output pulse. Plug-in type printed circuit board construction is used consisting of four boards, one for each channel.

II. Analysis

The logic unit consists of four channels which are the klystron body current, fast and slow, the klystron magnet current, and the arc detector. The detector used to trigger the klystron body fast and slow is basically a dc current sensor that generates a pulse when a high current goes through it due to an arc in the tube or the body current drifts to some predetermined value. It also generates a voltage proportional to the body current; this voltage is used in the slow channel. The klystron is also protected against magnet failure by another dc sensor, the output of which goes to the klystron magnet channel. The final channel is activated by an arc detector which senses waveguide arcs. The klystron body fast channel and arc detector are triggered from a positive pulse generated by the sensor when an overcurrent condition exists, such as a klystron arc. The klystron magnet and body overcurrent are triggered when a predetermined dc point is reached. The sequence of events is as follows: When the klystron arcs, it is detected by a sensor (such as a pulse transformer) in less than a microsecond and delivered to the crowbar logic unit. The klystron body fast channel is then triggered and shapes the pulse in less than 200 nanoseconds. This new pulse is then used to trigger the photon generator (which is a zenon-pulsed tube) and activates a light-sensitive SCR on the ignitron's high-voltage deck. This is then built up to a 2000-volt pulse, 10 microseconds long, that is applied to the ignitor and causes the ignitron to conduct and divert (discharge) the stored energy in the filter. All this takes place in approximately 10 microseconds.

The fast (pulse) channels operate in the following manner (refer to Fig. 1): A positive-going pulse of approximately 10 microseconds and 5 to 7 volts in amplitude is received by the logic channel. The first stage is a Schmitt trigger, which will change to a negative state when actuated by a positive pulse. The level is determined by adjusting the threshold voltage to any predetermined value—in this case, two volts. When the amplitude is greater than four volts, the Schmitt trigger is flipped to the negative state. This negative trigger is differentiated and the positive portion is clipped. It is then used to trigger IC2, which is a monostable multivibrator that produces a single pulse 50 microseconds wide. This pulse is then power-amplified by a high-level bootstrap emitter follower which will generate 20–25 volts at 1 ampere. This pulse is then applied to the photon trigger generator through a coaxial cable. The delay through the channel from the Schmitt trigger to the bootstrap is no greater than 200 nanoseconds.

The second half of each channel is the indicating portion. This is used for external indications that a particular channel has been fired, thus enhancing transmitter troubleshooting. IC3 operates identically to IC2, only the pulse width is increased to 70 milliseconds. Q2 generates a negative gate when IC1 is triggered. Q2 is used as a negative-going gate to activate an external indicator.

The level-sensing channel (Fig. 2) is similar to the pulse channel, except for the front end. It must be capable of detecting a level change (dc). The klystron magnet must trigger the unit when there is a decrease in magnetic field (magnet failure). Therefore, an inverting amplifier is used in conjunction with a bias voltage. The bias voltage is adjusted to buck the voltage from the magnet sensor. When the magnet current decreases, the output of IC1 increases and activates the Schmitt trigger which initiates the trigger for the rest of the circuitry. The klystron body overcurrent channel is a non-inverting amplifier; when the body current increases to a predetermined point, the Schmitt trigger generates a pulse and fires the crowbar. Each channel has a separate indicating portion. The output of each channel is combined through blocking diodes and joined at a common output.

III. Summary

This crowbar logic unit was designed to meet the needs of the new 400-kW transmitter. The klystron operates at a higher voltage (70 kV). Since the energy in the filter increases with the square of the voltage, it became obvious that new high-speed and reliable circuitry would have to be developed. This was found in the new solid-state integrated circuits. As stated before, the sensor and logic unit has a delay of less than one microsecond. The old unit with sensors was greater than 2000 microseconds. The response time of this logic unit, along with the rest of the system, should be adequate to protect the klystron from catastrophic events. This logic unit has been incorporated and is operational in the Mars, Venus, and X-band OCS sites.

Reference

1. Finnegan, E. J., "High-Power Transmitter Development," in *The Deep Space Network*, Space Programs Summary 37-40, Vol. III, pp. 83–84. Jet Propulsion Laboratory, Pasadena, Calif., July 31, 1966.

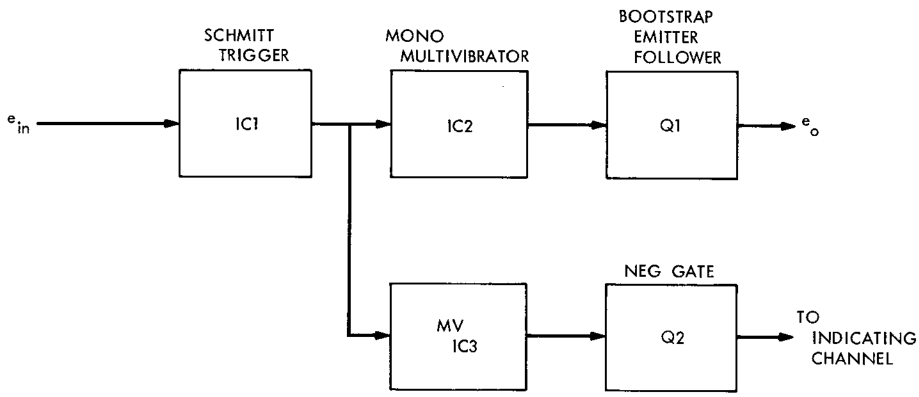

Fig. 1. Fast pulse channels

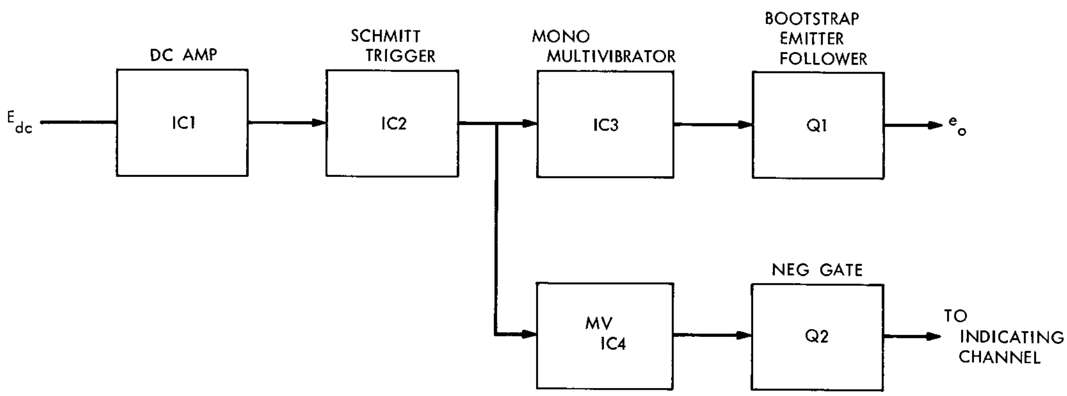

Fig. 2. Level-sensing channels